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ENGINEERING REPORT

FAA CONTRACT NO. DTFA03-02-C-00044
Project Relational Database
Q11 Version Documentation

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Enabling Technologies

Revision A: Extensive revision from the initial database report, which no longer reflects the database status. Revised to update the documentation to current database capabilities as of Q11, and to add instructions for beta testing. Re-organized sections, added tutorial and beta-test data retrieval.

INTRODUCTION

This report documents the relational database supporting the Destructive Evaluation of a Retired Transport Aircraft. This database contains a large volume of data collected over the course this research effort, including data from fractography, NDT inspections, and the full scale testing of crown skin panels. This database complements a series of written reports that lead to a project final report to be published at project's end.

This database is anticipated to be the ideal tool to distribute the results of this research to the industry. It is created in MS Access, a common PC application included in MS Office Professional. MS Access is a relational database that interacts well with data created in MS Word and MS Excel. The Database is designed to be distributed as a collection of data CD's, with most of the storage media dedicated to the photographs and NDT screen captures.

Because of the large volume of data collected, the most important feature of the user interface is the capability for standard queries, parametric studies, and reports to filter data as needed. User expertise in MS Access will not be required for typical use. However, users will be able to design very sophisticated custom data queries, since MS Access includes a graphical query builder and supports SQL statements.

This report provides an introduction and documentation of the database in four sections:

– Section 1 provides an overview of the database, including installation instructions, a data type overview, and some critical nomenclature.

- Section 2 is a tutorial, walking the user step-by-step through the most important features of the database and its user interface. This tutorial provides training to the new user, and also provides a standard test script for beta testing during database development.

– Section 3 is a more detailed look at the database structure. The fields for each of the primary tables is discussed, as are the more significant queries and reports. For the beta-test version, this section is provided for testers who wish to explore the database in depth beyond the scripted tutorial.

– Section 4 is a discussion of features that are planned for future versions of the database. This section is only applicable during the workscope of this project; at final database release at the end of the project, Section 4 will be removed.

LIST OF COMMON ACRONYMS

DVI	Detailed Visual Inspection
FS	Fuselage Station (Aircraft Coordinate System)
GVI	General Visual Inspection
MOI	Magneto-Optical Imaging
MS	Microsoft Corporation
NDI	Non-Destructive Inspection
OLE	Object Linking and Embedding - Microsoft's framework for a compound document technology
SB	Service Bulletin
SEM	Scanning Electron Microscopy
SQL	Structured Query Language
VB	Visual Basic

LIST OF COMMON FILE EXTENSIONS

*.jpg	Joint Photographic Experts Group (for compressed graphics, typically large photographs)
*.mdb	Microsoft Access database
*.pdf	Adobe’s Portable Document Format (typically for large, read-only documents)
*.tif	Tagged Image Format (for graphics, typically scans or other monochromatic images)
*.txt	Text (for unformatted text or numbers)
*.xls	Microsoft Excel (for formatted tables of text or numbers)

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1 SYSTEM REQUIREMENTS AND INSTALLATION

The Database was created using MS Access for Windows 2000. The computer must have this version or later of MS Access installed for the database to open. The database has been tested successfully with MS Access 2002.

The MS Access database cannot run directly from the CD or any other read-only directory. However, the majority of the data can reside on a CD, and external hard drive, or the PC's hard drive.

The database only requires that the MS Access file be installed on the user's PC - the pictures and documentation can reside on the CD's. All data for a section of the fuselage is together on the same CD. The general project documentation and this report are on Disk 0.

1.1 MINIMUM REQUIREMENTS FOR DATABASE INSTALLATION

- At least 45 MB is required for a minimum installation.
    a) A complete installation of the current version requires 3 GB.
    b) It is expected that 10 GB will be required for complete installation of the final version.
- Requires installation of MS Access 2000 or higher, with its associated system requirements:
    a) Personal computer with Pentium 75-MHz or higher
    b) CD Drive
    c) Disk Space: 30 MB
    d) Ram: 128 MB for Windows XP plus 8 MB for MS Access
- Requires applications to view attached files
    a) Adobe Reader for documentation in Adobe's Portable Document Format (pdf).
    b) MS Paint, MS Document Imaging, or other applications that can view compressed graphics files in the Joint Photographic Experts Group (jpg) and tagged image file format (tif) formats.

1.2 TO INSTALL AND RUN

Insert "Disk 0: Database and Documentation" into the PC

Copy the file "727-Q11.mdb" to a convenient place on your computer (requires 45 Mb)

Graphics files are viewed in the application associated by Windows with the file extension. To change the graphics viewer, change the application associated with “jpg” and “tif” extensions in MS Windows.

1.3 DATA TYPES INCLUDED

There are three broad data types collected by the database:

Tabular Data – Data stored as records within a table. These tables contain much the numeric and textual data from this project, such as crack measurements, qualitative indices, comments, and inspections results. Tabular data is stored within the MS Access Database.

Graphic Data – Data stored as a graphics file. This data type consists primarily of screen shots taken during NDT inspections, and photographs, stereo micrographs and fractographs taken during damage characterization. Graphic data require a significant amount of storage space, so only the pathnames to these files are stored within the database tables. The graphics files (typically *jpg or *.tif) are stored outside the database, either on CD’s or on the user’s hard-drive.

Documentation Data – Data stored as a complete report document. Data of this type includes the most current deliverable reports under this project’s work scope, including this report. At final delivery, it will include reports of addressing all of the procedures, analysis, results, recommendations, and conclusions resulting from this project. These reports are stored in Adobe’s Portable Document Format (*.pdf). All documentation is stored on Disk 0, and a link within the user interface leads to the documentation.

1.4 NAMING CONVENTIONS

Each aircraft location related to data within the database has been identified with a standard address termed the ShortCode. The ShortCode is the primary key in many of the database tables, and it is through the ShortCode that all data for a specific location are linked.

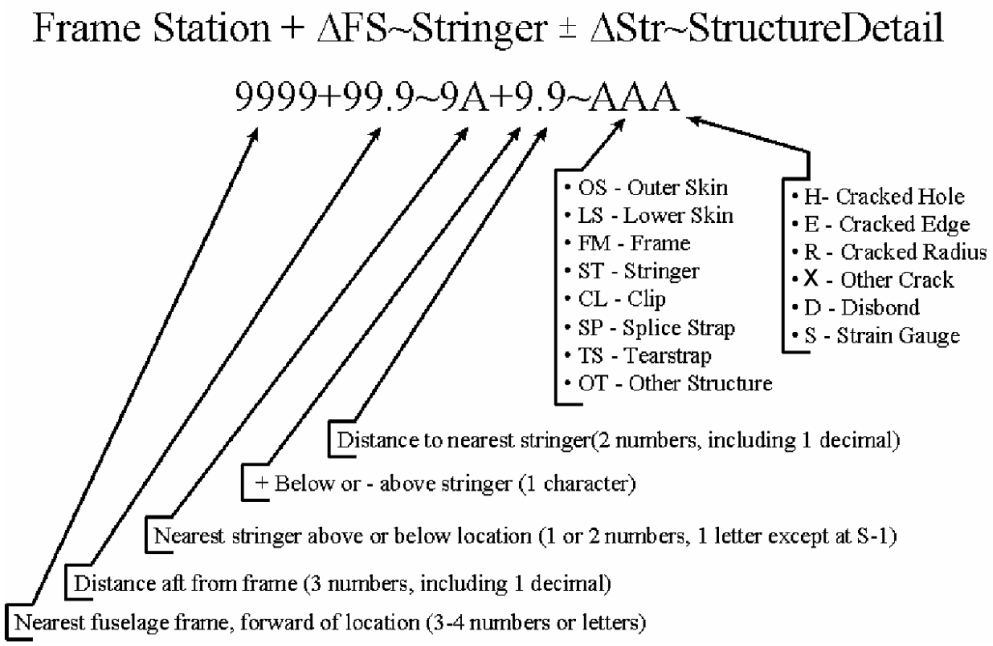


Figure 1-1: Location Naming Convention

The first term of the ShortCode is the fuselage station forward of the location. Fuselage Stations (FS) for the B727-200 are shown in Figure 1-2. FS numbers in the B727-100 simply reflect inches aft of a forward datum, but with the additional fuselage plugs in the 727-200, the figure below is required. The second term of the ShortCode is the location's offset aft (in inches) from the reference frame. A tilde (~) separates these frame numbers from the subsequent stringer terms.

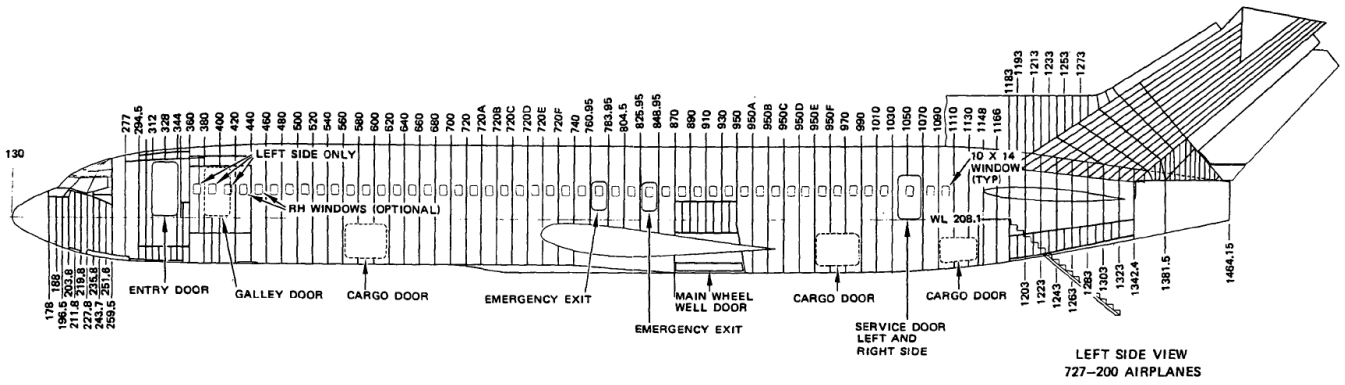


Figure 1-2: Fuselage Station Diagram

The third term in the ShortCode is the nearest stringer to the location. Stringers are numbered from Str-1 on the crown center line to Str-30 on the bilge centerline. Except for Str-1 and Str-30, all stringers are labeled left or right. For example, the two uppermost lap joints are at Str-4L and Str-4R on the left and right sides, respectively.

The forth term is the location's offset circumferentially (in inches) from the reference stringer. Since the stringer numbers increase from crown to bilge, a + offset is towards the bilge, while a – offset is towards the crown. For example, all locations on the lower row of the Str-4R lap joint will have a + 1.0 offset. Another tilde separates the stringer data from the 3 letter crack identifier. The crack identifier is a three letter code, as shown in the figure; the first two letter identify the structure affected (skin, splice strap, etc.), and the last letter identifies the crack geometry (from hole, from edge, etc.).

The ShortCode allows a knowledgeable user to decode a location without resorting to a specific damage map. For example, "540+11.0~4R+1.0~LSH" refers to a hole in the lower row, lower skin of stringer 4-right lap joint, 11 inches aft of the FS 540 frame.

For any location, especially a fastener hole, there may be more than one crack present. In this case, the primary keys are the ShortCode and a Crack Number. Crack Numbers are assigned in sequence starting from 1 according to Figure 1-3 below.

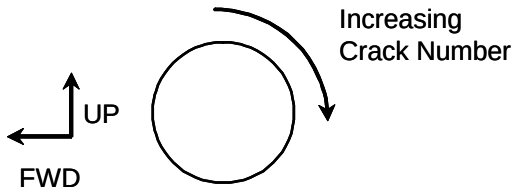


Figure 1-3: Crack Numbering Convention

2 TUTORIAL

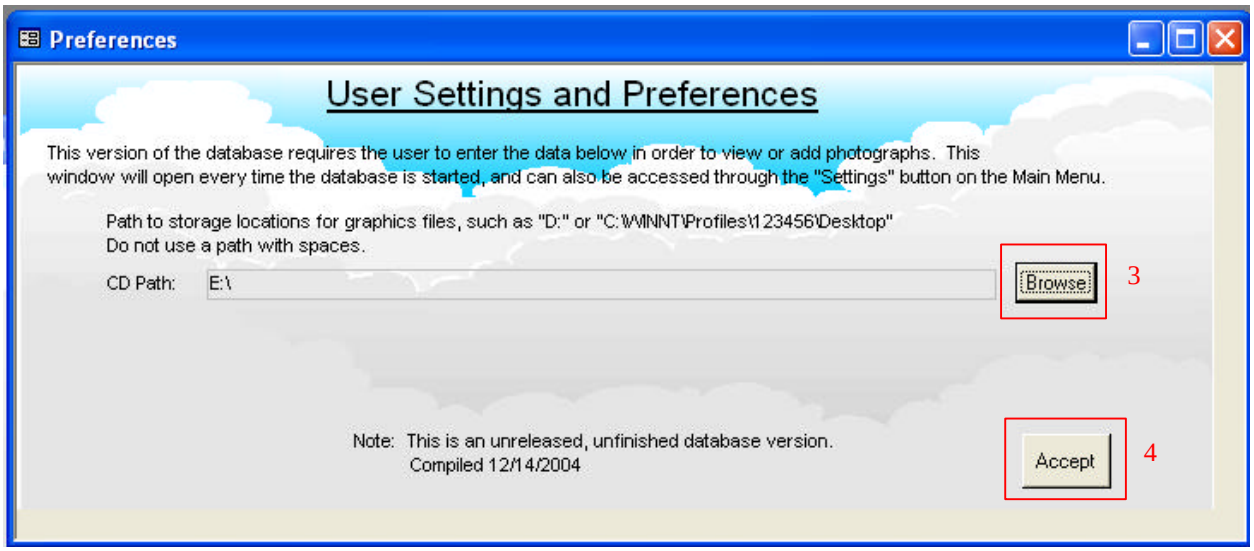
The purpose of the tutorial is to provide a quick walkthrough of the database functionality. In addition, the tutorial acts as an evaluation script for a standard beta test. A user questionnaire follows this tutorial/script in section 2.6. More detailed descriptions of the data tables are contained in section 3.

Please note that the database and its user interface are still under development, and that the windows, steps, and data shown in this tutorial may not fully reflect the user interface. For example, it is generally acceptable to click “Yes” to create a table when prompted, even if that step is not explicitly called out in this tutorial.

Step 1: Insert “Disk 0: Database and Documentation” into your computer’s CD drive.

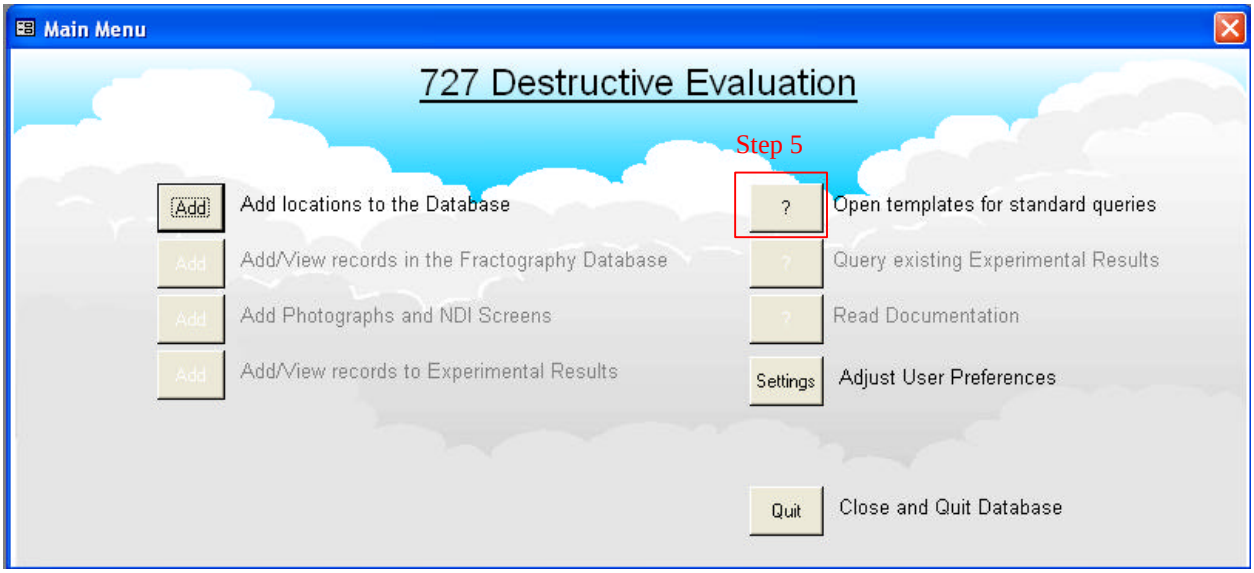
Step 2: Double-click on "727-Q9v2.mdb" on the PC

The database opens to the "User Settings" form.



Step 3: "Browse" to the CD drive letter (i.e., "E:\") and press "Accept". This setting allows for the minimum amount of data to reside on the PC, with the vast majority remaining on CD. If you prefer, you can copy the contents of all CD's to a hard drive - if so, then "Browse" to that location.

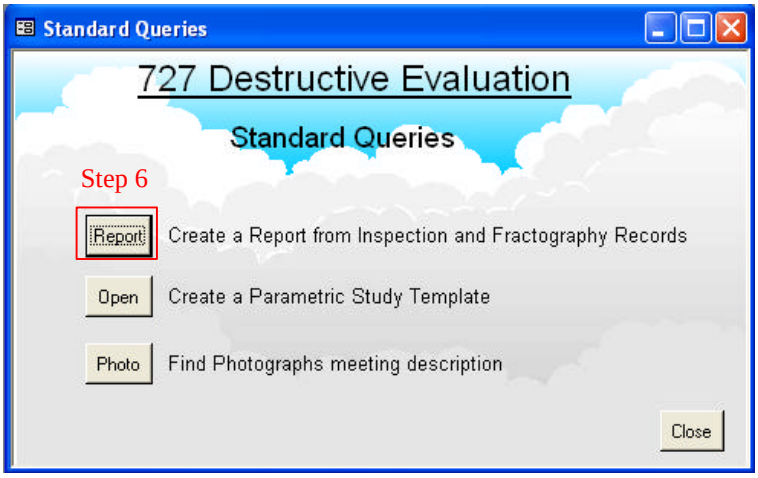
Step 4: Press “Accept”. The database will open the “Main Menu” form.



This tutorial will run through three standard queries that have been developed. The tutorial provides an introduction to the volume of fractography and NDI assessment data available in this relational database. More detailed information on the tables and queries is contained in Section 3.

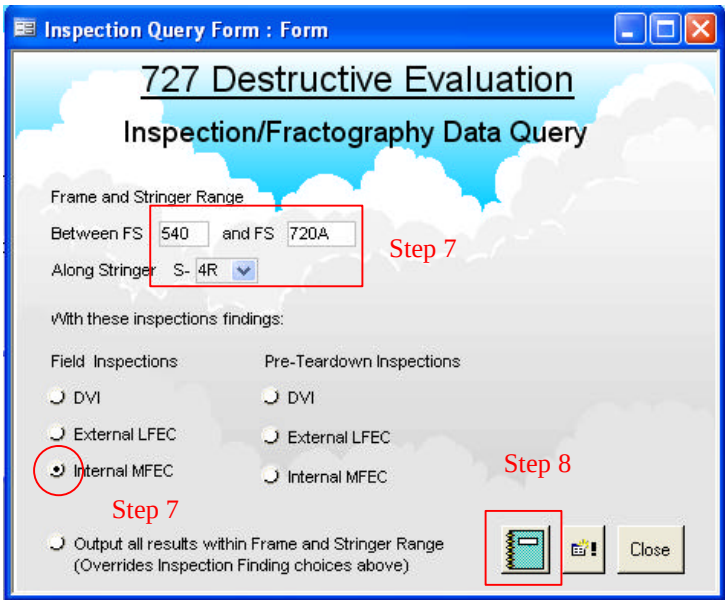
2.1 CREATE A REPORT OF INSPECTION AND FRACTOGRAPHY RECORDS

Step 5: Press "?" to open to Standard Queries form. This form is a menu leading to three query builders. Press "Report" to create an integrated report from NDI and Fractography records.

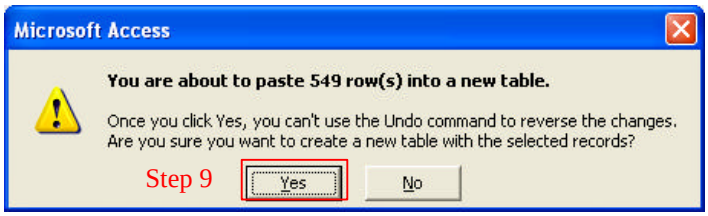


Step 6: Press "Report" to open the Inspection/Fractography Data Query form. This form allows the user to construct a printed report combining inspection and damage characterization results for select locations.

Step 7: Fill in values for the Fuselage Station range and stringer as shown above. The form can filter results to only those with specific inspection findings, or you can "Output all results".



Step 8: Press  to generate the report. The database creates a new table with the results of your query, so Access will prompt with a message box similar to the below.



Step 9: Press "Yes" to create a table of query results. A preformatted report will be created, similar to that shown below.

540+05.7~4R+1.0~LSH

Field Inspections

R	*DVI*	R	*MFEC (Fwd)*		
NF	*LFEC*	R	*MFEC(Aft)*		

Fastener and Hole Quality Parameters

AFT+60	*Rivet Tilt*	*Corrosion:*	No Significant
0.106	*Max Tail Height*	*Hole Quality:*	Significant circ. flaws
0.082	*Min Tail Height*	*Surface Defects:*	Light gouges w/scratches
0.214	*Fwd/Aft Diameter*	*Fretting/Galling:*	No Significant
0.21	*Other Diameter*		
Yes	*Unbroken Edges*	*Deformed Metal*	Edge deformation w/ little overflow
No	*Drill Shavings*	*Hole Cracked:*	Yes

Pre-Teardown Inspections

R	*DVI*	R	*MFEC (Fwd)*	–	*SAM*
NF	*LFEC*	R	*MFEC(Aft)*	R	*C-scan*
NR	*Rivetcheck(Fwd)*	NF	*MOI (Fwd)*	–	*Film X-ray*
NF	*Rivetcheck(Aft)*	NF	*MOI (Aft)*	–	*Digital X-ray*
–	*MWM (Fwd)*	R	*TurboMOI(Fwd)*	–	*Trescan*
–	*MWM (Aft)*	R	*TurboMOI(Aft)*	NF	*Array EC*
–	*Rotoscan*	–	*Rasterscan*	–	*ACES*
–	*Eddyscan*	R	*NASA GMR*	–	*RFEC*

Figure 2-1: Inspection Report

This report integrates the most significant fractography and inspection data for all locations within the selected range. The specific location shown, 540+05.7~4R+1~LSH, is in the lower row, lower skin, of the stringer 4R joint. The results for each inspection method are coded as follows:

– "--" : the inspection was not performed

– "NF": the inspection was successfully performed, and resulted in no crack findings

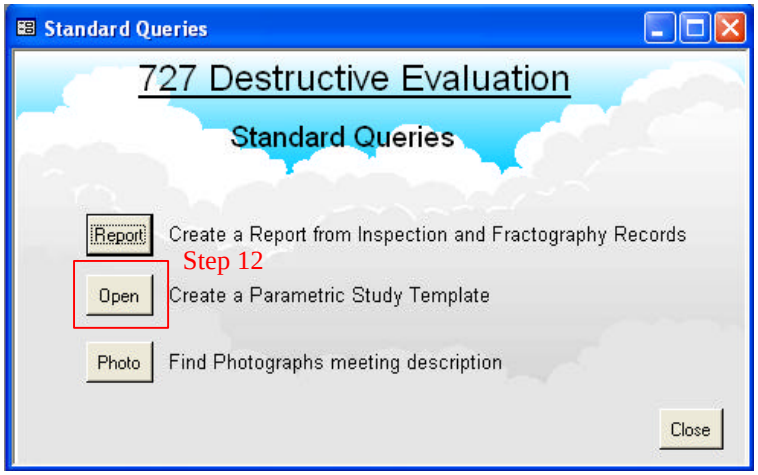
– "NR": the inspection was successfully performed, with no definitive crack indications that are rejected (i.e., called suspect) by the inspection procedure. However, characteristics in the NDT return suggests that cracking may exist that is below the detectable threshold.

– "R": the inspection was successfully performed, and returned a rejectable crack indication.

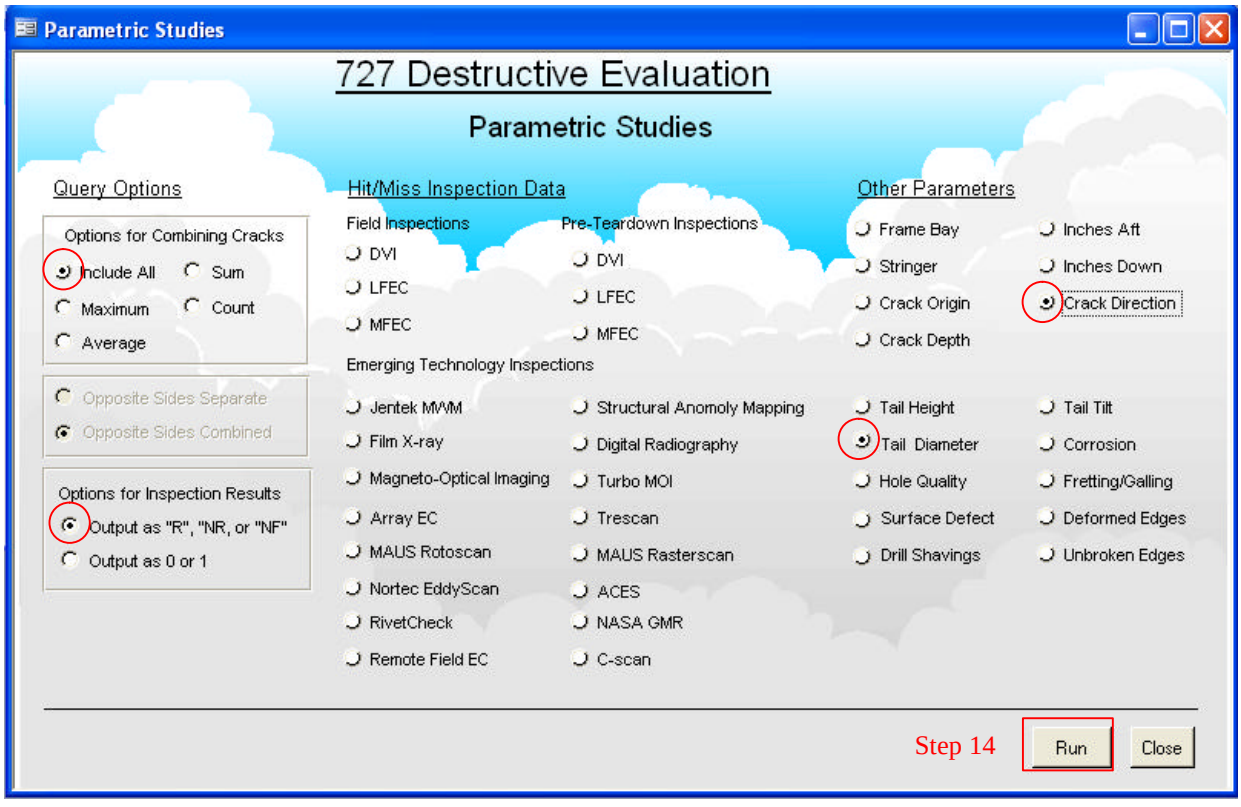
Step 10: Press “Close” above the report to return to the Inspection/Fractography Data Query form.

Step 11: Press “Close” on the Inspection/Fractography Query Form to return to the Standard Queries form.

2.2 CONDUCT A PARAMETRIC STUDY OF CRACK INITIATION



Step 12: From the Standard Queries form, Press "Open" to open the Parametric Studies form.



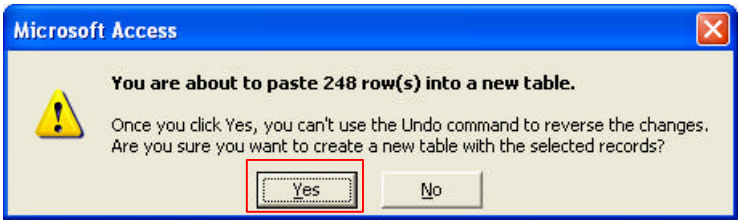
This form creates a table of results for the parameters you choose to include. Use the radio buttons to select between study options.

Some fastener holes were found to have four or more cracks on the same side of a fastener hole. The "Options for Combining Cracks" determines how to treat these cases – whether each crack is be output separately, or if an aggregate function such a "maximum" or "average" is be used to

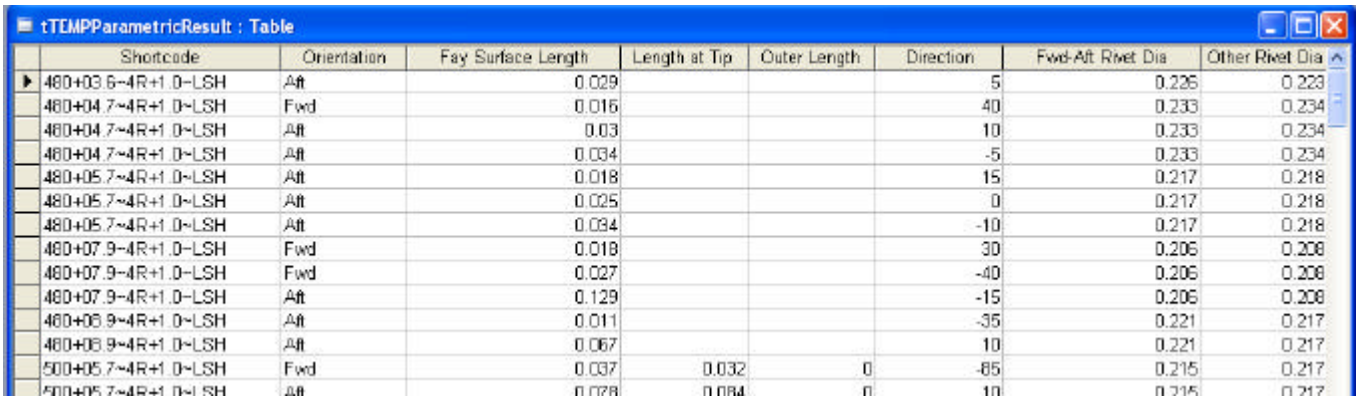
combine them. Crack level parameters "Crack Origin", "Crack Direction", and "Crack Depth" are only available if "Include All" is selected. For this tutorial, use the radio button to select "Include All".

Step 13: Select parameters to be output in the parametric study. For this tutorial, select "Crack Origin" and "Tail Diameter"

Step 14: Select "Run" to start the query.



Step 15: Select "Yes" to create the table of results. All results should have at least one of three possible lengths reported: length along the faying surface, length at the crack tip, and length opposite the faying surface.



Shortcode	Orientation	Fay Surface Length	Length at Tip	Outer Length	Direction	Fwd-Aft Rivet Dia	Other Rivet Dia
480+03.6~4R+1.0~LSH	Aft	0.029			5	0.226	0.223
480+04.7~4R+1.0~LSH	Fwd	0.016			40	0.233	0.234
480+04.7~4R+1.0~LSH	Aft	0.03			10	0.233	0.234
480+04.7~4R+1.0~LSH	Aft	0.034			-5	0.233	0.234
480+05.7~4R+1.0~LSH	Aft	0.018			15	0.217	0.218
480+05.7~4R+1.0~LSH	Aft	0.025			0	0.217	0.218
480+05.7~4R+1.0~LSH	Aft	0.034			-10	0.217	0.218
480+07.9~4R+1.0~LSH	Fwd	0.018			30	0.206	0.208
480+07.9~4R+1.0~LSH	Fwd	0.027			-40	0.206	0.208
480+07.9~4R+1.0~LSH	Aft	0.129			-15	0.206	0.208
480+08.9~4R+1.0~LSH	Aft	0.011			-35	0.221	0.217
480+08.9~4R+1.0~LSH	Aft	0.067			10	0.221	0.217
500+05.7~4R+1.0~LSH	Fwd	0.037	0.032	0	-85	0.215	0.217
500+05.7~4R+1.0~LSH	Aft	0.078	0.084	0	10	0.215	0.217

Figure 2-2: Table Resulting of Parametric Study Query

The intended functionality is that this table of data is ready to be exported into another application for analysis. Exporting data from MS Access to MS Excel is relatively seamless as both Microsoft Office applications. If desired, copy the "Fay Surface Length" and "Direction" columns in the database, and then "Paste Special" as text into Excel. Using the "Chart Wizard" and some formatting, you can plot the results as shown below.

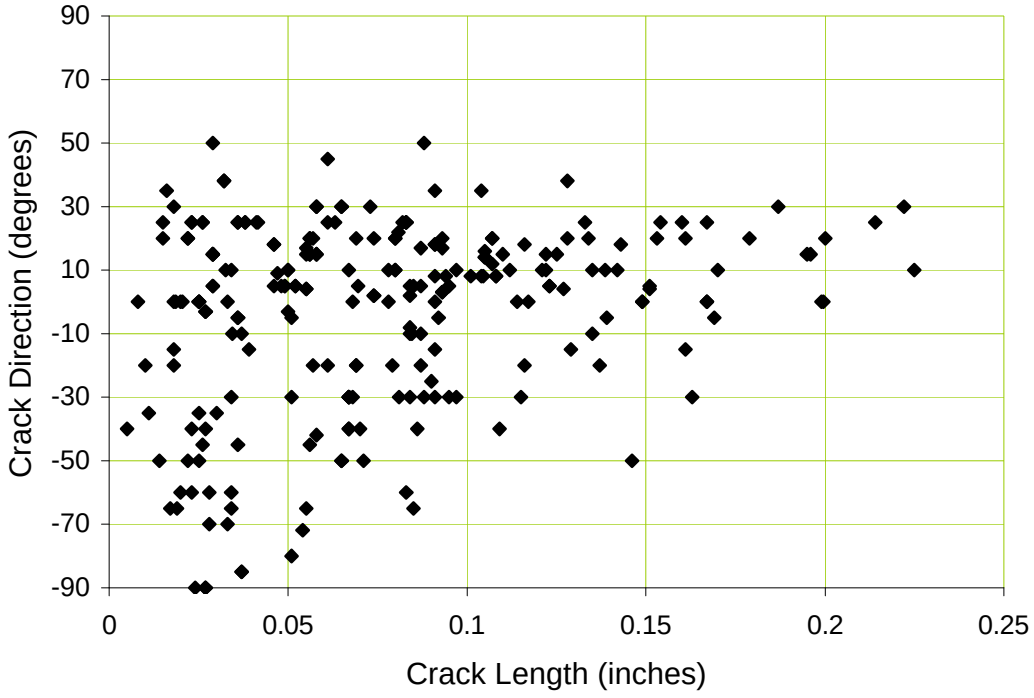
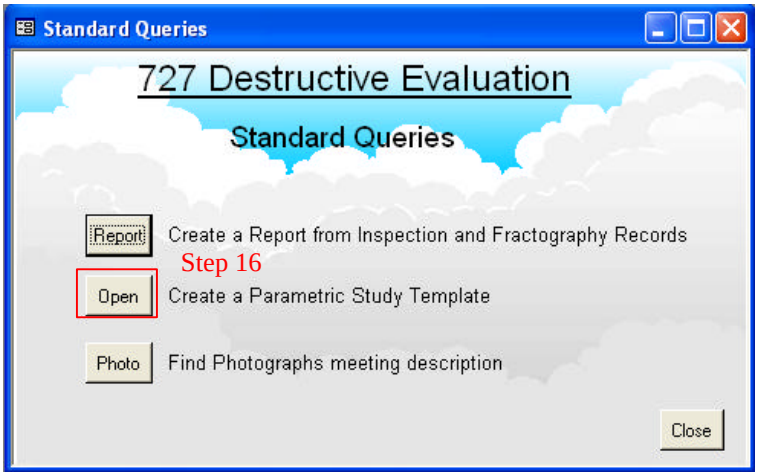
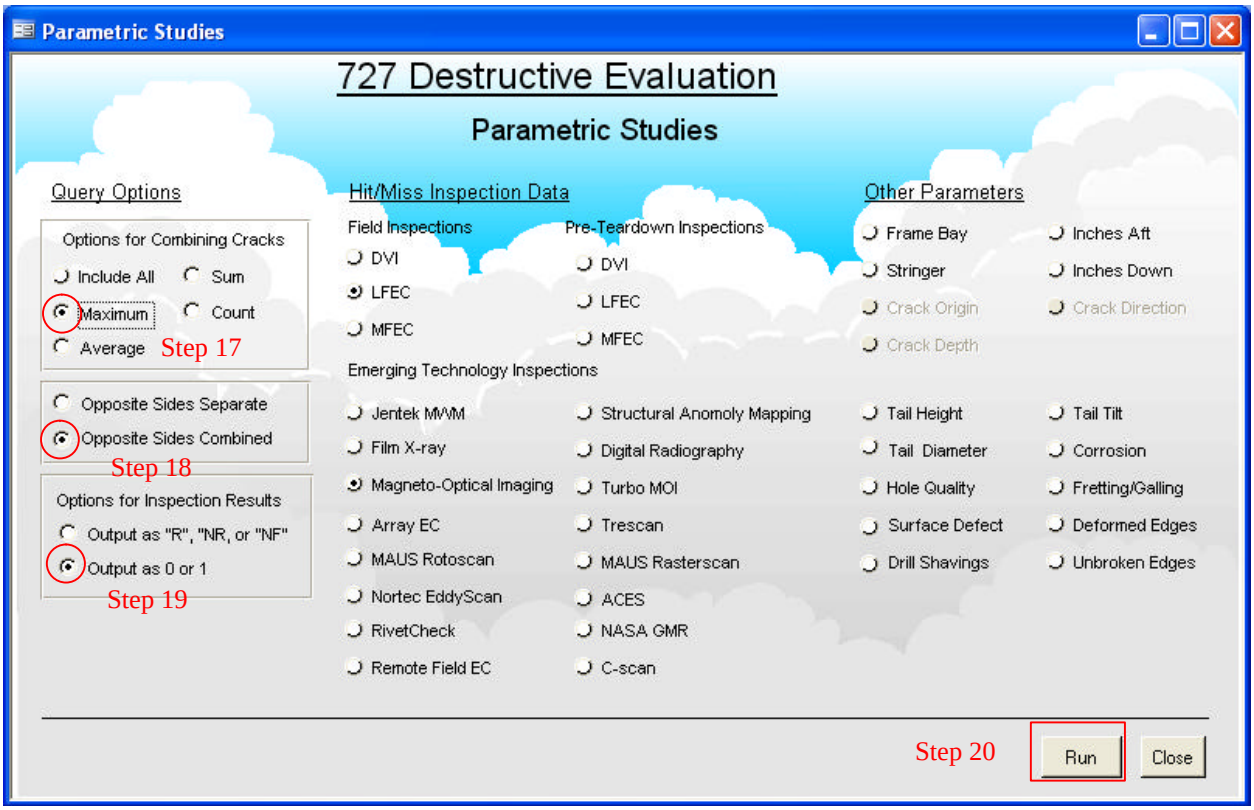


Figure 2-3: Example Plot of Crack Direction vs Crack Length Parametric Results

2.3 CONDUCT A PARAMETRIC STUDY OF CRACK DETECTION



Step 16: From the Standard Queries form, Press "Open" to open the Parametric Studies form.

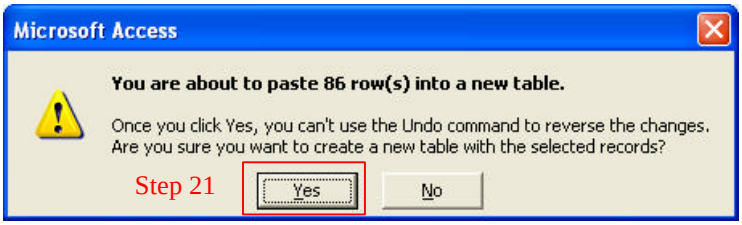


Step 17: Under "Options for Combining Cracks" select "Maximum".

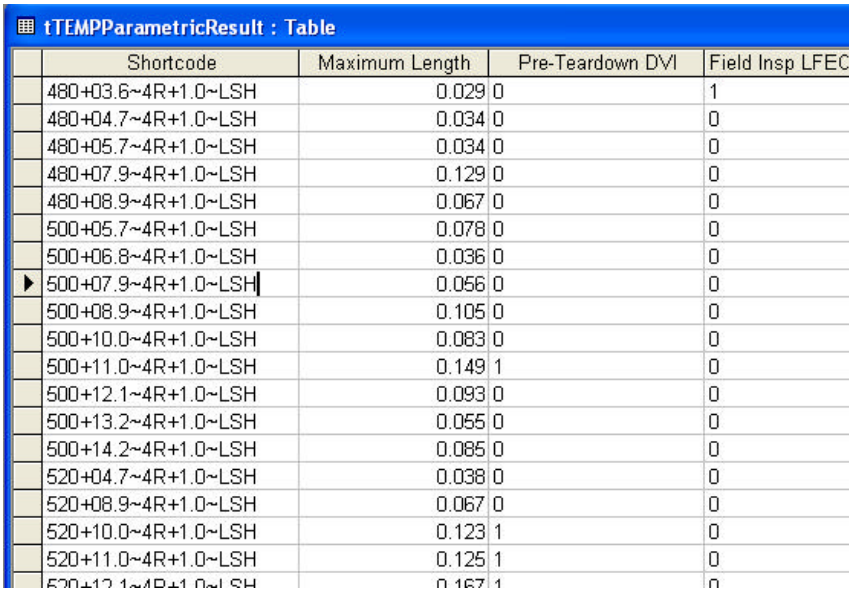
Step 18: Select "Opposite Sides Combined". Selections in steps 17 and 18 together will return the single largest crack at each hole location.

Step 19: Select “Output as 0 or 1”. This option returns all rejectable indications as 1, all non-rejectable indications and misses as 0, and all locations with no inspection as “-- “.

Step 20: Select “Run” to start the query.



Step 21: Select “Yes” to create the table of results.



Shortcode	Maximum Length	Pre-Teardown DVI	Field Insp LFEC
480+03.6~4R+1.0~LSH	0.029	0	1
480+04.7~4R+1.0~LSH	0.034	0	0
480+05.7~4R+1.0~LSH	0.034	0	0
480+07.9~4R+1.0~LSH	0.129	0	0
480+08.9~4R+1.0~LSH	0.067	0	0
500+05.7~4R+1.0~LSH	0.078	0	0
500+06.8~4R+1.0~LSH	0.036	0	0
500+07.9~4R+1.0~LSH	0.056	0	0
500+08.9~4R+1.0~LSH	0.105	0	0
500+10.0~4R+1.0~LSH	0.083	0	0
500+11.0~4R+1.0~LSH	0.149	1	0
500+12.1~4R+1.0~LSH	0.093	0	0
500+13.2~4R+1.0~LSH	0.055	0	0
500+14.2~4R+1.0~LSH	0.085	0	0
520+04.7~4R+1.0~LSH	0.038	0	0
520+08.9~4R+1.0~LSH	0.067	0	0
520+10.0~4R+1.0~LSH	0.123	1	0
520+11.0~4R+1.0~LSH	0.125	1	0
520+12.1~4R+1.0~LSH	0.167	1	0

Figure 2-4: Table Resulting of Parametric Study Query

If desired, as in the previous section, “Copy” and “Paste Special” as text the Length, DVI, and LFEC columns into MS Excel. Using the “Chart Wizard” and some formatting, can create a plot of the detailed visual inspection results as shown below.

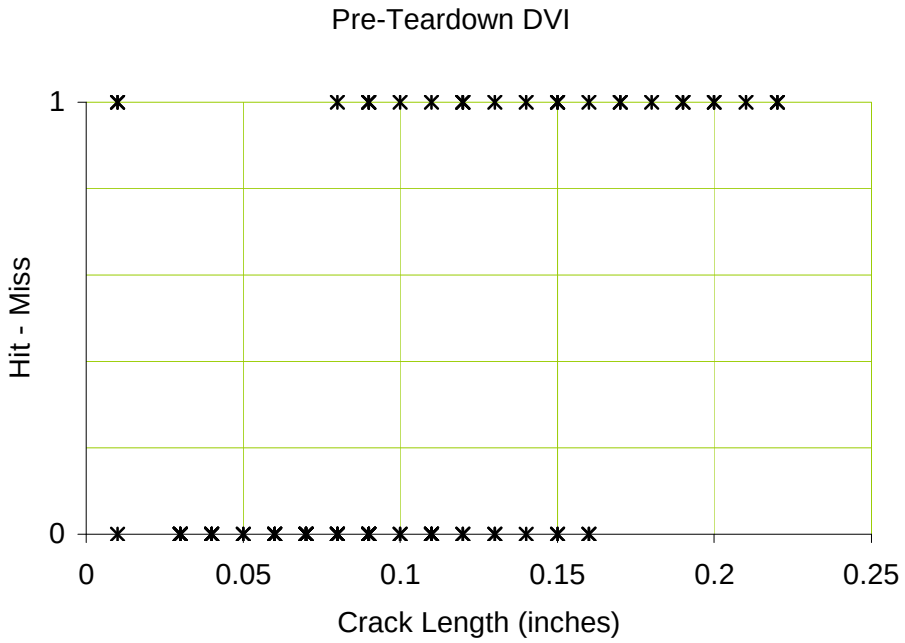
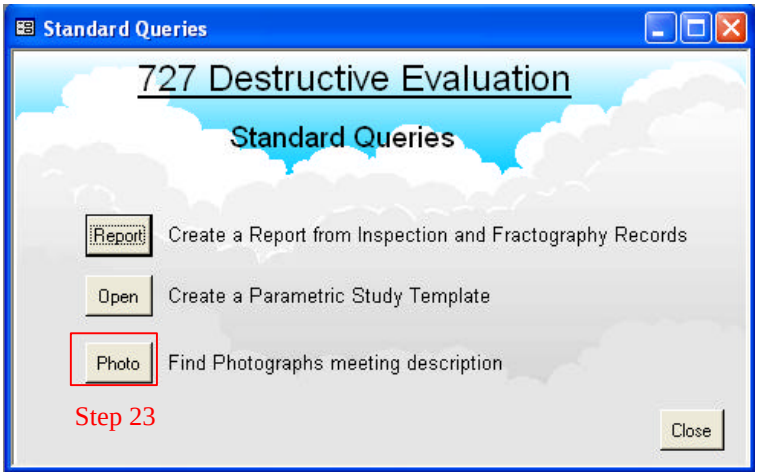


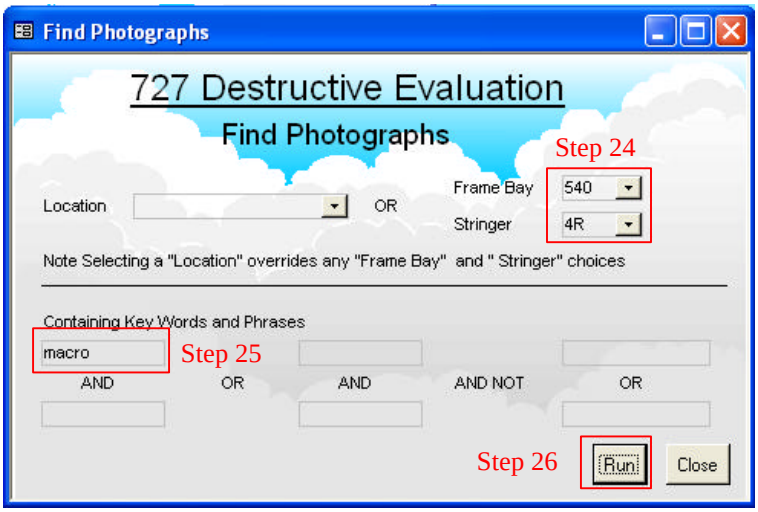
Figure 2-5: Example of Hit-Miss Data Plot

2.4 FIND PHOTOGRAPHS MEETING DESIRED CONDITIONS



Step 22: Put “Disk 1: FS 340 - FS 560”, the CD containing the all graphics forward of FS 560, into the CD drive

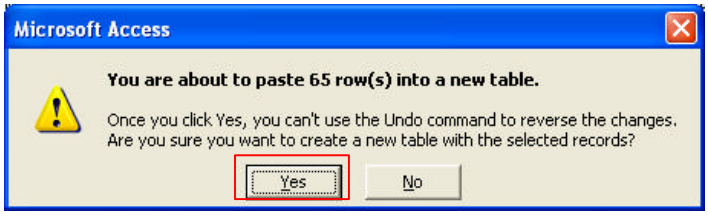
Step 23: From the Standard Queries form, Press “Open” to open the Photograph Query form.



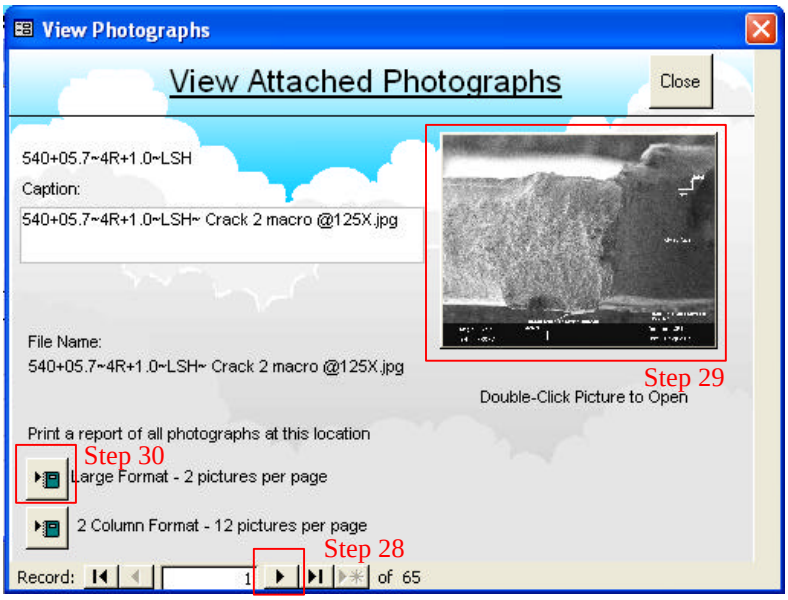
Step 24: Use the pull down menus to select frame bay “540” and Stinger “4R”. This selection filters the query result to the selected frame bay.

Step 25: Type the word “macro” into upper left box of the Boolean search field. This search will find all photographs along Stringer 4R, FS 540 - FS 560, with “macro” included in the photo caption.

Step 26: Press "Run" to start the search



Step 27: Select "Yes" to create the table of results. At Q11 there will be several prompts in sequence; respond "Yes" to each, even to create 0 rows.



From this form, you have several options:

Step 28: Press ▶ (the "Next Record" button) to advance through the photographs, and ◀ to move back.

Step 29: Double click directly on the picture to open the photograph in a separate application. The picture will open in the application associated with that specific file type (most commonly *.jpg). See Operating System documentation for instructions to change file associations.

Step 30: Press Large Format to create a report with two photographs per page, as shown in Figure 2-6. This report allows the user to print a hard copy of the query result at an acceptable detail level.

Step 31: Press "Close" to close the Large Format report and return to the View Attached Photographs form.

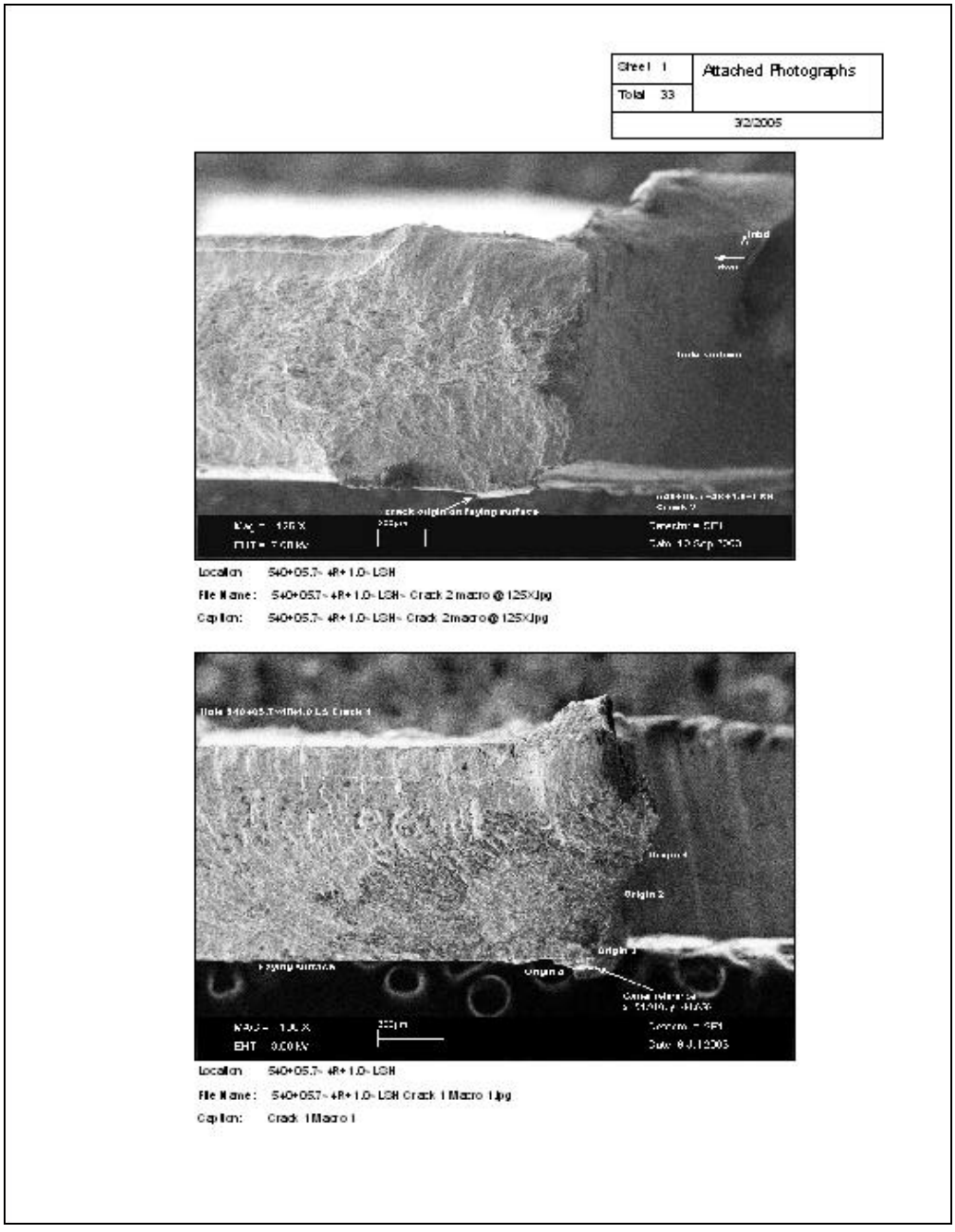
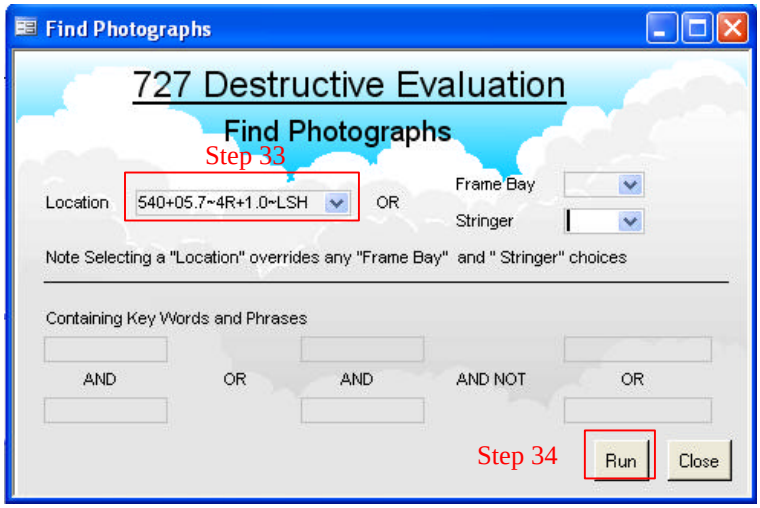


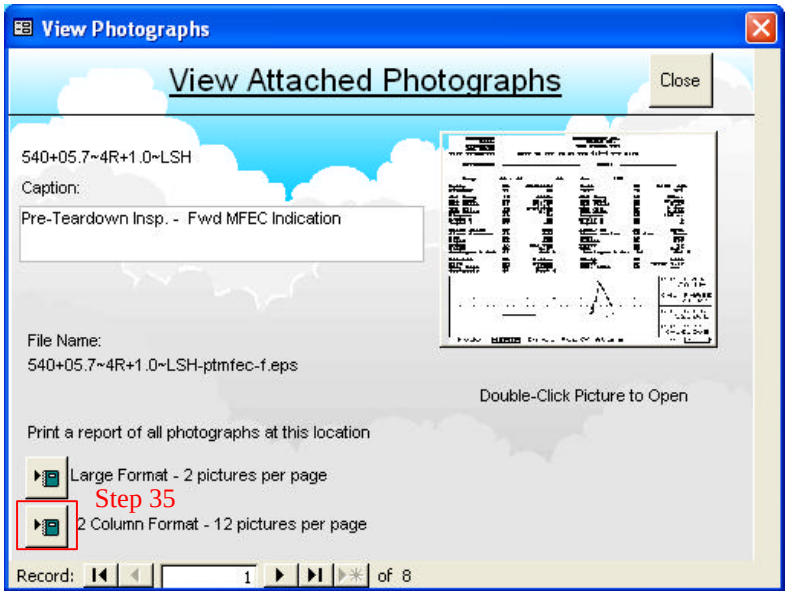
Figure 2-6: Large Format Report with Two Photographs per Page

Step 32: "Copy" the ShortCode "540+05.7~4R+1.0~LSH" from the View Photographs form, then press "Close" to return to the Photograph Query form.



Step 33: Paste the ShortCode "540+05.7~4R+1.0~LSH" into the location field, and clear the other query fields (or type 540+05.7~4R+1.0~LSH into the box). This query will retrieve all photographs associated with at this single location.

Step 34: Press "Run" to start the query, then press "Yes" to display the results.



Step 35: Press  "2 column format" to create a report with thumbnail view of all pictures, as shown in Figure 2-7. This report allows the user to view a large number of photographs at once, albeit at a low detail level.

There are two groups of pictures that will be returned. First will be graphics that are applicable to the complete frame bay 540~4R, such as NDI techniques including x-ray and MWM. Second will be those graphics associated only with location 540+05.7~4R+1.0~LSH.

In addition, the graphics for this location will be sorted by keywords in the photo caption In general, for any specific location, a query returns graphics in order by:

- Frame bay, then location
- NDI screens, from Standard to Emerging
- Stereo fractographs, from low magnification to high
- SEM fractographs, from origin to crack tip

Sheet 2	Attached Photographs
Total 23	
7/10/2005	

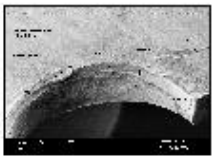
Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH-ftmfec-a.eps

Caption:
Eddy Current Inspection - Aft MFEC Indication

Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH~Inside hole view.jpg



Caption:
540405.7~4R+1.0~LSH~Inside hole view.jpg

Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH-ftmfec-f.eps

Caption:
Eddy Current Inspection - Fwd MFEC Indication

Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH Crack 3 Origin in hole 500x.jpg

Caption:
Crack 3 Origin in hole 500x

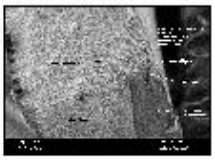
Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH-ptmfec-f.eps

Caption:
Pre-Teardown Insp.- Fwd MFEC Indication

Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH Crack 3 Origin in hole 200x.jpg



Caption:
Crack 3 Origin in hole 200x

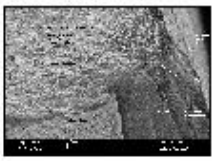
Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH-ptmfec-a.eps

Caption:
Pre-Teardown Insp.- Aft MFEC Indication

Location
540405.7~4R+1.0~LSH

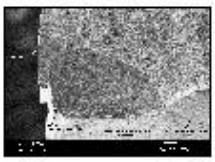
File Name:
540405.7~4R+1.0~LSH-Crack3 Origin in hole 500x.jpg



Caption:
540405.7~4R+1.0~LSH~Crack3 Origin in hole 500x.jpg

Location
540405.7~4R+1.0~LSH

File Name:
540405.7~4R+1.0~LSH Crack 3 Whole crack at 200x.jpg



Caption:
Crack 3 Whole crack at 200x

Location
540405.7~4R+1.0~LSH

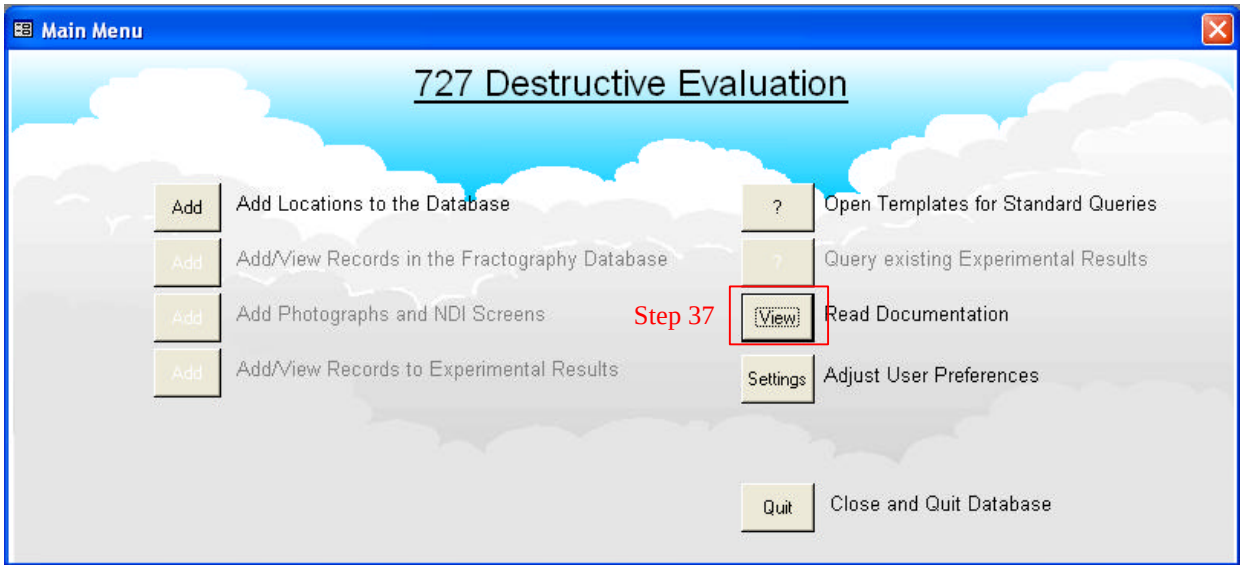
File Name:
540405.7~4R+1.0~LSH~Crack 3 Inside hole.jpg

Caption:
540405.7~4R+1.0~LSH~Crack 3 Inside hole.jpg

Figure 2-7: Two Column Report

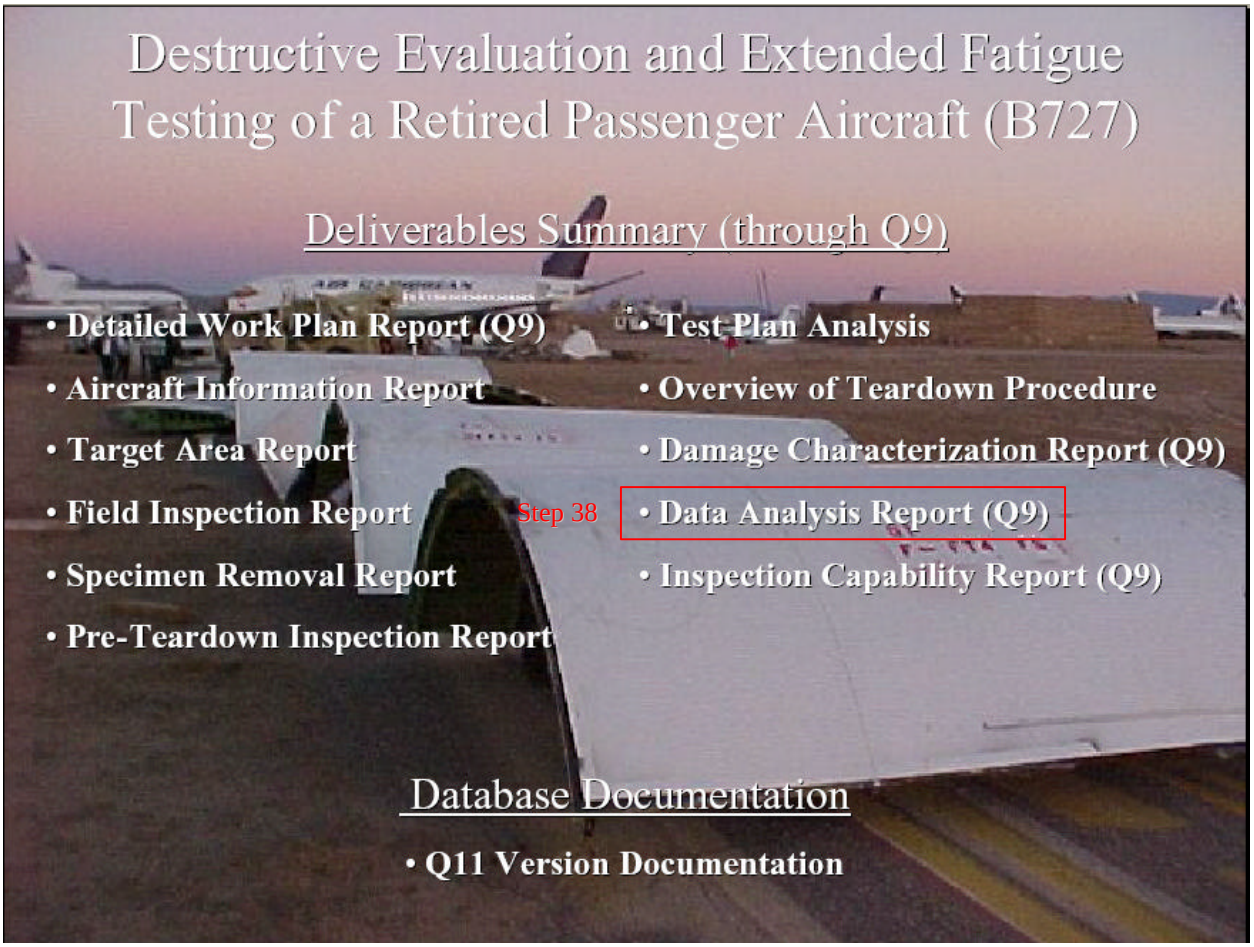
2.5 VIEW DOCUMENTATION

The documentation is stored in Adobe's *.pdf format, and includes all of the contract deliverables developed to date.



Step 36: Ensure that "Disk 0: Database and Documentation" is in the correct disk drive.

Step 37: From the Main Menu, select "View" to open the documentation menu. The Documentation Menu will open in Adobe Reader or Adobe Acrobat.



Step 38: For this tutorial, click on "Damage Characterization Report". The report will open in the same Reader window, as shown in Figure 2-8. Note that this report is available at this screen as well.

Step 39: To return to the Documentation Menu, press "Shift + Alt + ⇦" (Shift, Alt, and left Arrow simultaneously). Or, press escape and select "Edit\Go to Previous View" from Adobe's pull down menu.

SHEET	i	4-087051-20
TOTAL	v	

CODE	1500-9-1
ISSUE DATE	10/09/03

REVISION					
No.	PAGE	DATE	No.	PAGE	DATE
A	thru	01/30/04	E	Chpts 1,3,4,6-9	12/22/04
B	Chpts 1,3,4, 9	3/26/04			
C	Chpts 1,2,9	6/30/04			
D	Chpts 1,6,7,9	10/08/04			

ENGINEERING REPORT

FAA CONTRACT NO. DTFA03-02-C-00044
PHASE 3, CLIN 0003c(3)

Q9 Data Analysis

Distribution
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Principal Engineer
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General Manager
Enabling Technologies

Revision E: Revised to update as Q9 Data Analysis Report. Chapter 1 adds a summary of progress during Q9 to the existing progress summaries. Chapters 3 and 4 (FEA Analysis), 7 (Crack Growth), 8 (Initiation), and 9 (Analysis Supporting Testing) revised to reflect the current level of progress.

PROPRIETARY DATA - RESTRICTED DISTRIBUTION - CONTROLLED BY TERMS OF FAA AGREEMENT

Figure 2-8: First Page of Data Analysis Report

2.6 BETA TEST QUESTIONNAIRE

Thank you for your effort in completing the tutorial. Please complete the Beta Test Questionnaire, Sections 1 and 2, and return it with any additional comment sheets to the fax number below. E-mail to david.steadman@delta.com is also welcome.

To: David Steadman, Delta Air Lines

Fax: 404-714-5791

Voice: 404-714-0057

From:

Fax:

Voice:

Questionnaire Section 1

Based on your expected use of the data within this database, please rate the features listed below in their expected usefulness to you and your research. Please list any features that that are not included but would be helpful to you in an separate comment sheet.

	Must Have: A Feature I Will Use Extensively	Feature I Want	Feature I Might Use	Feature I Probably **Do Not** Need
1 Report of Inspection and Fractography Records (Steps 5 - 11)	---	---	---	---
1.1 Print a report combining NDI and characterization results for an area				
1.2 Print a report for fasteners other than the lap joint critical rows				
1.3 Output report data as a table				
1.4 Combine tabular results and graphics in a single report*				
2 Conduct a Parametric Study (Steps 12 - 21)	---	---	---	---
2.1 Combine crack lengths using maximum, average, etc.				
2.2 Distinguish between multiple cracks at a specific hole location				
2.3 Conduct a parametric study including rivet installation and hole quality parameters				
2.4 Filter installation/quality results to specific parameters				
2.5 Conduct a parametric study including NDI inspection results				
2.6 Output inspection data as “R”, NR”, or “F”				
2.7 Filter inspection results to specific NDI types				
2.8 Copy/Paste results into another application, such as MS Excel	---	---	---	---
3 Find Photographs (Steps 22 - 35)				
3.1 View all graphics for a specific location				
3.2 View all graphics for a specified area (e.g., a frame bay)				
3.3 Compare NDI results and micrographs for a specific location				
3.4 Filter graphics by keyword using the Boolean query builder				
3.5 Print a two-graphics per page report				
3.6 Print a two-column report (12 graphics per page, thumbnail sized)				
4 Documentation (Steps 36 - 39)	---	---	---	---
4.1 View Documentation on the database itself (e.g., this report)				
4.2 View Background data on aircraft usage, project work scope, etc.				
4.3 View project Results and Conclusions*				
5 Features Not Listed (attach additional sheets if necessary)	---	---	---	---

* Feature not present in current database version

Questionnaire Section 2

Based on your experience completing the tutorial , please rate the features listed below and their interfaces on their operation and ease of use.

* For any features that are less than acceptable, please provide additional information on a separate comment sheet.

	Very Intuitive: No Problems Using	Interface is Acceptable	Interface Needs Improvement *	Interface and/or Feature Does Not Work *
1 Report of Inspection and Fractography Records (Steps 5 - 11)	---	---	---	---
1.1 Print a report combining NDI and characterization results for an area				
1.2 Print a report for fasteners other than the lap joint critical rows				
1.3 Output report data as a table				
2 Conduct a Parametric Study (Steps 12 - 21)	---	---	---	---
2.1 Combine crack lengths using maximum, average, etc.				
2.2 Distinguish between multiple cracks at a specific hole location				
2.3 Conduct a parametric study including rivet installation and hole quality parameters				
2.4 Filter installation/quality results to specific parameters				
2.5 Conduct a parametric study including NDI inspection results				
2.6 Output inspection data as “R”, NR”, or “F”				
2.7 Filter inspection results to specific NDI types				
2.8 Copy/Paste results into another application, such as MS Excel	---	---	---	---
3 Find Photographs (Steps 22 - 35)				
3.1 View all graphics for a specific location				
3.2 View all graphics for a specified area (e.g., a frame bay)				
3.3 Compare NDI results and micrographs for a specific location				
3.4 Filter graphics by keyword using the Boolean query builder				
3.5 Print a two-graphics per page report				
3.6 Print a two-column report (12 graphics per page, thumbnail sized)				
4 Documentation (Steps 36 - 39)	---	---	---	---
4.1 View Documentation on the database itself (e.g., this report)				
4.2 View Background data on aircraft usage, project work scope, etc.				
4.3 View project Results and Conclusions				
5 Features Not Listed (attach additional sheets if necessary)	---	---	---	---

3 DETAILED DATABASE INFORMATION

3.1 DOCUMENTATION OVERVIEW

3.1.1 STATEMENT OF WORK REQUIREMENTS

This database supports Task 12 of FAA Contract DTFA03-02-C-00044, Documentation and Database Development. The Statement of Work requires that the databases be developed using commercially available software. Databases delivered shall also include documentation on database structures, data record specifications, their usage and data retrieval. Data within the scope of the Initial Database includes:

- Rational for selection of the aircraft and structure analyzed
- Procedures and data from field and pre-teardown inspections
- Procedures used to remove structure from the aircraft
- Data and results of all inspections including delivery of signal response data in the form of an electronic database
- Data characterizing the state-of-damage including:
- Fatigue crack distributions, locations, shapes and sizes
- Damage initiation mechanisms and locations
- Reconstructed fatigue crack growth histories
- Quantification of corrosion, disbonds, fretting damage at faying surfaces, and other damage

3.1.2 DATA FORMATS

The data collected and developed for this project are captured electronically in two forms. General documentation reports of the aircraft service history, teardown procedures, fractography methods, database documentation, etc. are stored in an Adobe® Portable Document Format (*.pdf). The more specific data such as NDI findings fastener parameters, crack measurements, microscope photographs and SEM striation counts are collected in a Microsoft® Access Database.

These two formats were chosen in part because of they are readily available and in wide use throughout the aerospace industry. Microsoft® Access is a component of Microsoft® Office, a common suite of productivity software. The Adobe® Acrobat® Reader is available free of charge at http://www.adobe.com.

Within the database there are three broad data types :

Tabular Data – Data stored as records within a table. These tables contain all the quantitative data from this project, such as crack measurements and inspections results. These tables also include qualitative data in tabular form, such as the qualitative hole quality indices and comments collected during inspections and fractography. Tabular data is stored within the MS Access Database.

Graphic Data – Data stored as a graphics file. This data type consists primarily of screen shots taken during NDT inspections, and photographs, stereo micrographs and fractographs taken during damage characterization. Graphic data require a significant amount of storage space, and are stored as individual files outside of the MS Access Database. The MS Access Database records associate tabular data to the pathname of each graphic file. These files are stored in one of several common compressed graphic file formats, either *.jpg or *.tif.

Documentation Data – Data stored as a complete report. Data of this type includes the most current deliverable reports under this project's work scope, including this report. At final delivery, it will include reports of addressing all of the procedures, analysis, results, recommendations, and conclusions resulting from this project. These reports are stored in Adobe's Portable Document Format (*.pdf).

3.2 TABULAR DATA

Tables store the collection of data, and are the most basic structure within a database. Each row in the table is a record, which corresponds to one unique instance of an object or event. Each column in the table is a field, which corresponds to one property or quality applicable to each object. For example, each record within the Field Inspection table corresponds to a specific location, and the results from each type of NDI inspection type are fields. Fields can be formatted as numbers, text, Booleans, or OLE objects.

The Database is relational, so the data tables are linked through the key fields. Data records are defined on one of three levels, as listed below. This data structure is important towards maximizing the performance of the database, as large data structures that are underused are inherently wasteful and can kill the performance of a large database like this one.

A primary data key is a field or sequence of fields which uniquely defines the data record, so it cannot contain duplicates. For example, at the location level, the location short code uniquely defines the position, so no duplicates are permitted and only one record per location is allowed. At the crack level, many cracks at the same location are permitted, so the location and crack number together make the record unique.

- Location Level: includes data which is valid for one location, typically a hole, regardless of the number or absence of detected cracks. Primary Key: ShortCode (see section 3.2.1)

- Crack Level: includes data that is valid for only one of (possibly) several cracks at the same fastener or damage location. Primary Keys: ShortCode and Crack Number (see section 3.2.2)

- Striation Level: includes data that is valid for only small area on a fracture surface, typically defined by SEM stage coordinates. Primary Keys: ShortCode, Crack Number, and Striation Number (see section 3.2.2.2)

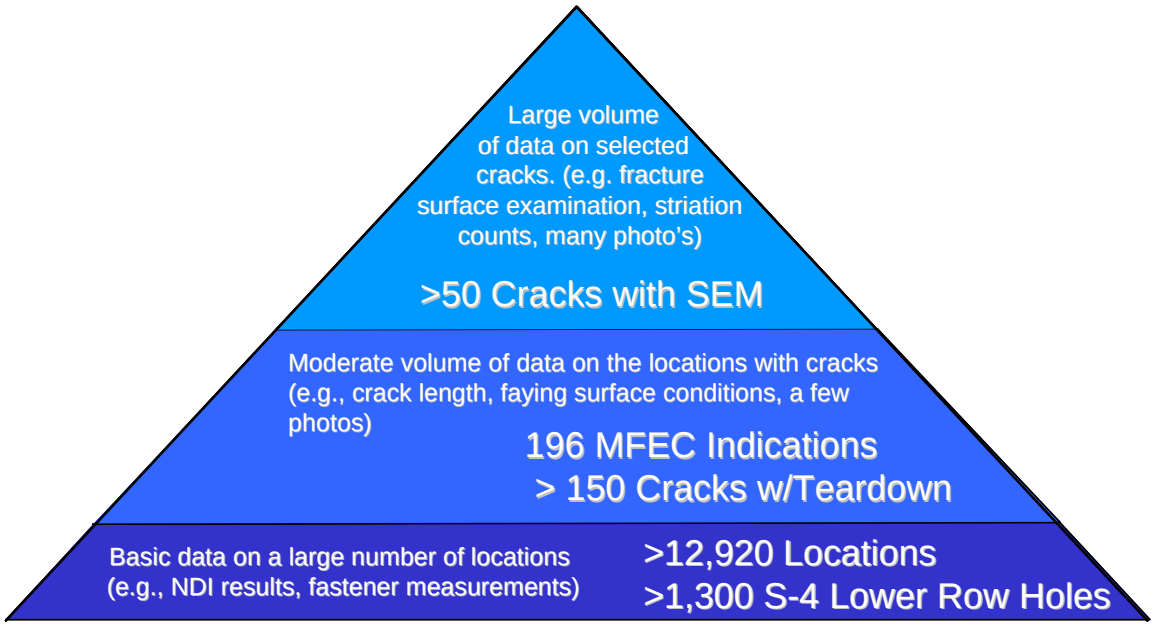

Figure 3-1: Schematic of Data Requirements

3.2.1 LOCATION LEVEL TABLES

Most locations in the database correspond to a single fastener locations. For example, the lower row fastener hole in the lower skin at S-4R, FS 442.6 is a single location. Data locations can also be defined on stringers, clips, frames, and tearstraps. A standard nomenclature for locations is shown in Figure 3-2. The nomenclature has 6 terms within 3 groups: a) the lateral location, b) the circumferential location, and c) the structure and type of crack. This standard format has several advantages:

The format allows someone experience with the project to know exactly where on the aircraft the damage was located, without reference to a special map. FS stations and stringer numbers can be determined from a general Fuselage Station drawing, or measured directly from the structure.

The format is expandable, so that new crack geometries or structures outside of those anticipated to crack can be readily identified.

The format contains no characters that are unacceptable for a filename under MS Windows. This allows all computer files associated to a crack location to include the location identifier in the filename.

The format works even in the fuselage plug sections. Fuselage station (FS) numbers on the 727-100 are equal to the distance aft (in inches) from a reference point 178" forward of the forward pressure bulkhead. The 727-200 has two fuselage plugs to extend its length 240" over the 727-100, but the fuselage station for the structure shared by both types retains its original FS number. Therefore, 727-200 FS numbers are not simple measurements from a reference point, and FS stations for frames in the plugs section are text, such as "720A" (see Figure 3-3).

- There are four location level tables, where the ShortCode is the sole primary key, discussed in subsequent sections:

- Photographs contains all of the graphic files associated with a specific locations.

- tFieldInspection contains the results of the visual and standard NDT inspections performed in the field prior to aircraft disassembly.

- tInspectionResults contains the results of the visual, standard NDT, and Emerging NDT inspections performed in a controlled environment after aircraft disassembly, but before fastener removal.

- Fractography contains all of the location level data from the Damage Characterization. Note that much Damage Characterization data is at the Crack or Striation level.

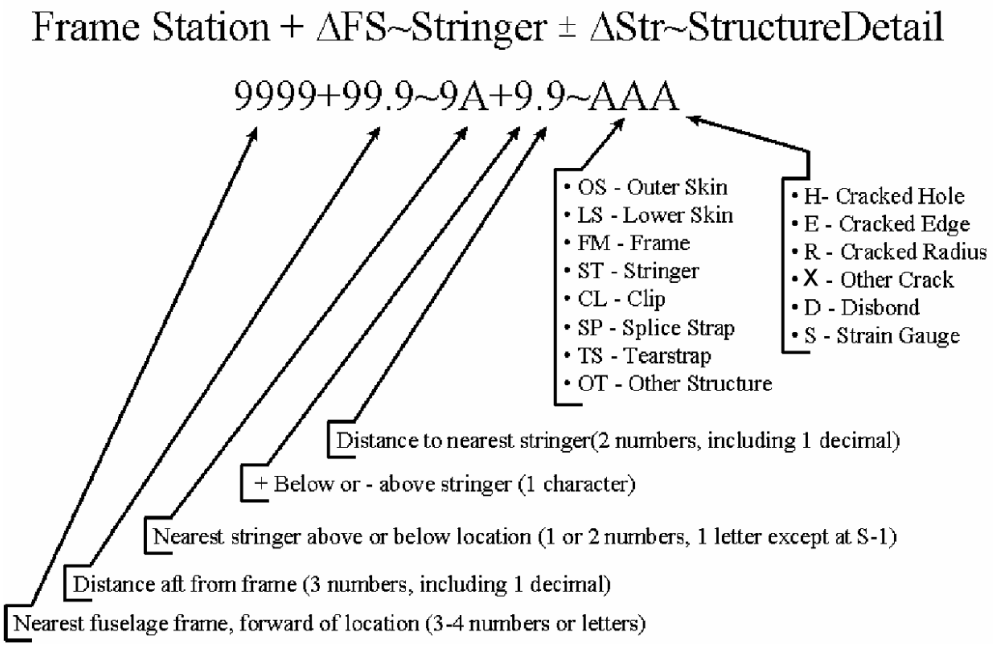

Figure 3-2: Nomenclature for Damage Location Key (ShortCode)

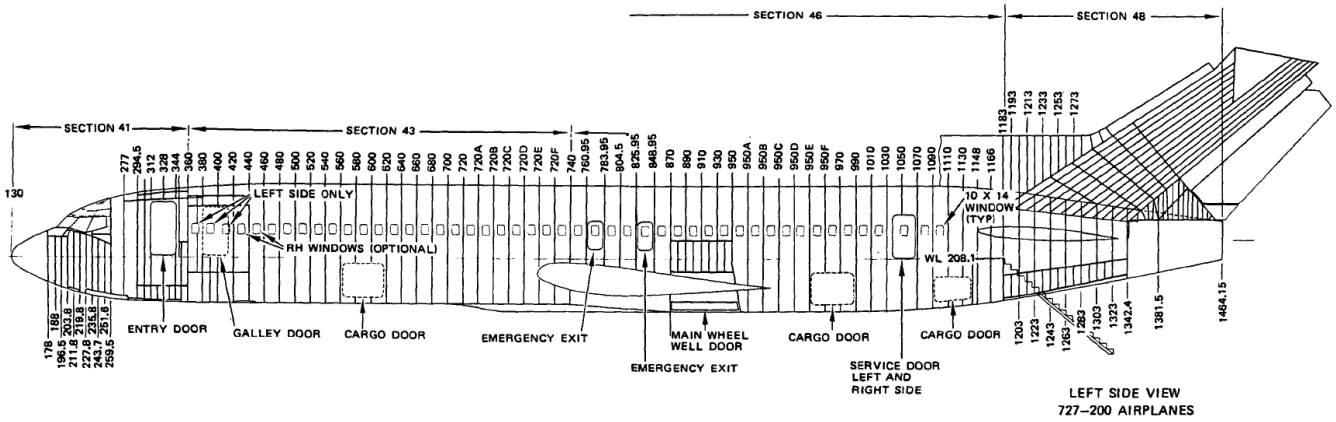

Figure 3-3: 727-200 Fuselage Stations

3.2.1.1 Photographs

This table contains information for all of the photographs and NDT screen captures gathered throughout the program that are associated with a specific ShortCode. There are only three fields in this table in addition to the ShortCode:

- Photo Link, which is the file name of the graphic image
- Caption, which is the caption to be attached to the image.

See section 3.2.5.1 for the similar BayPhotographs table.

3.2.1.2 fFieldInspection

The results of visual and NDT inspections accomplished at each subject location. For high resolution inspections that discriminate between different cracks, separate results are reported for the forward and aft sides of a fastener hole. At each location, the inspection result is reported as one of the following:

- "--" : the inspection was not performed
- "NF": the inspection was successfully performed, with no crack findings
- "NR": the inspection was successfully performed, with no rejectable crack indications. However, characteristics in the NDT return suggests that cracking may exist that is below the detectable threshold. These results are subjective and based on comments from the NDT inspector.
- "R": the inspection was successfully performed, and returned a rejectable crack indication. For standard NDT techniques, these results are objective and based on well-defined threshold criteria.

3.2.1.3 tInspectionResults

This location level table contains the inspection results for three series of inspections:

- the Field Inspection, performed outdoors on aircraft before disassembly in Victorville, CA.
- the Pre-Teardown Inspection, performed using standard NDI techniques in a controlled, workbench environment after panel removal.
- The Emerging NDI Inspections, performed using a variety of non-standard NDI techniques in a controlled, workbench environment after panel removal.

Results use the same nomenclature ("--", "NF", "NR", or "R") as in Section 3.2.1.1 above.

3.2.1.4 Fractography

This location level table contains quantitative measurements and qualitative metrics taken based on visual microscopy. Further details are outlined in the Q9 Damage Characterization reports. The field within this table include:

- Rivet driven head (i.e., rivet tail) diameter and height, measured in two places.

- Rivet tail tilt direction

- Hole Quality: a qualitative metric defined on the following scale:
  (1) Clean or with minor circumferential flaws only
  (2) Significant circumferential flaws
  (3) Circumferential flaws (minor or major) with minor axial flaws
  (4) Significant axial flaws

- Deformed metal at edge:
  (1) Clean, no deformed metal
  (2) Edge deformation (like a volcano)
  (3) Edge deformation with a little metal overflow
  (4) Edge deformation with a lot of metal overflow

- Drill Shavings Present (Yes/No)

- Unbroken hole edges (Yes/No)

- Faying surface defects:
  (1) Clean
  (2) Light scratches
  (3) Heavy scratches
  (4) Light gouges with or without scratches
  (5) Heavy gouges

- Drill shavings/metal adhered to surface: (Yes/No)

- Fretting/galling:
  (1) No significant
  (2) Mild galling
  (3) Heavy galling
  (4) Mild fretting (black oxide), with or without galling
  (5) Heavy fretting

- Corrosion/Corrosion Products:
  (1) No significant
  (2) Mild
  (3) Severe

- Visual Microscopy of Fracture Surface
- Crack length measurements a_1, a_2, a_3, and c (depth) are measured as shown in Figure 3-6.
- The crack geometry is selected from a drop down list
- a_1 is always longer than a_3. If a_1 is against the faying surface of the part, than it is a faying surface crack. a_2 is measured at the midpoint of c.

3.2.2 CRACK LEVEL TABLES

The following data is collected through this window: Figure 3-4

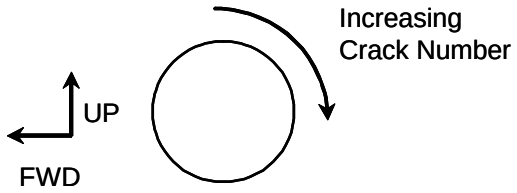

Figure 3-4: Nomenclature for Crack Key

There are two tables with data at the crack level:

- Fract Visual contains data collected during visual stereo microscopy of each fracture surface (see section 3.2.2.1).

- Fract SEM contains data collected during scanning electron microscopy of each fracture surface (see section 3.2.2.2). This table only contains data applicable to the entire fracture surface; see section 3.2.2.2 for discussion of SEM data on the striation level.

3.2.2.1 Fract Visual

This crack level table contains all data applicable to a specific crack that is obtained using the visual stereo-microscope. Field contained within this table include:

- Crack Orientation: The gross crack direction with respect to the aircraft cardinal directions of forward, aft, up (hoop +), down (hoop -), inboard, or outboard

- Origin Angle: The location on a fastener where the crack started, as shown in Figure 3-5. In the Figure 3-5 example, the origin of Crack 1 is 45^0.

- Crack Direction: The angle that best describes the crack direction from origin to tip, as shown in Figure 3-5. In the Figure 3-5 example, the direction of Crack 1 is 25^0.

- Crack Lengths: The measurement of the crack at up to three locations. For a through crack, those measurements would be along the faying surface, along the opposite surface, and the longest measured length. A depth is typically reported, equal to the skin thickness for a through crack. For a corner crack, the length measurements would include a crack length along the faying surface, the longest measured length, and the crack depth. See schematic in Figure 3-6.

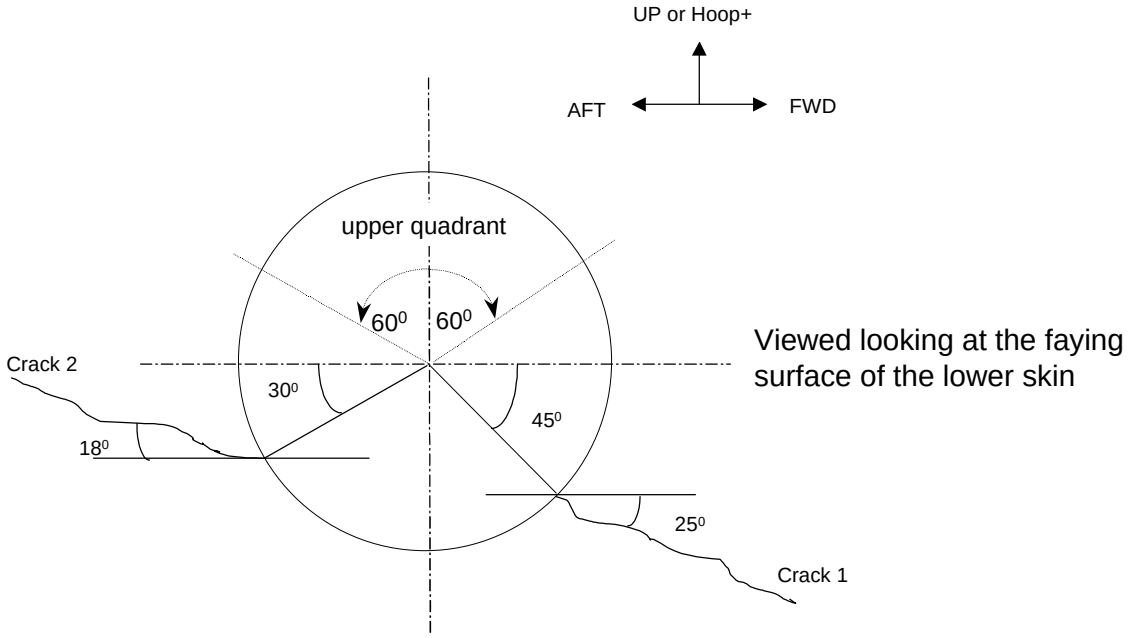

Figure 3-5: Hole Origin and Direction Example

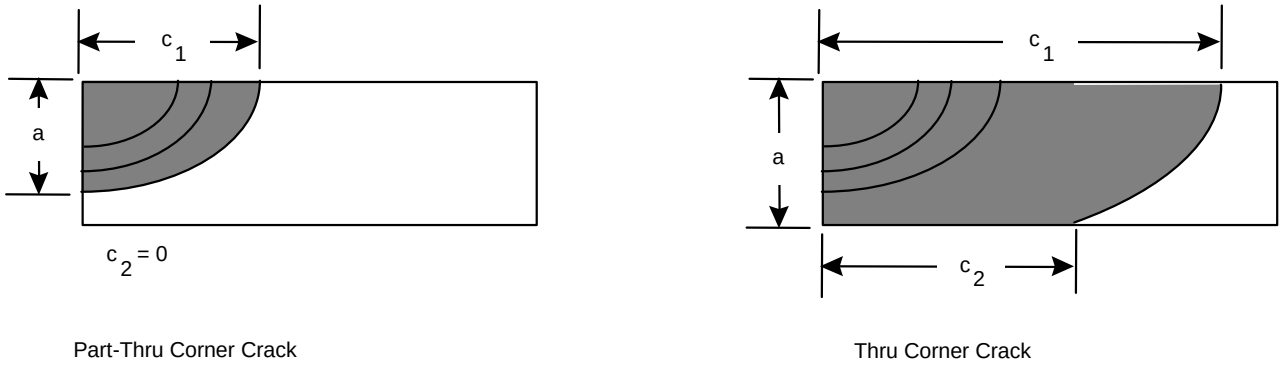

Figure 3-6: Measured Crack Lengths

3.2.2.2 Fract SEM

This table contains all data collected from the SEM that is applicable to the entire crack surface. Much of this data is a foundation for the striation level data discussed in section 3.2.3. The fields in this table include:

- Stage coordinates to establish the fracture reference grid. These coordinates consist of x and y stage measurements for a geometric reference point (e.g., the corner of the faying surface with the hole bore) and for a point along the faying surface.

- Coordinates and description for each significant crack origin.

- Description of ductile pop-ins or other signs of unstable crack growth.

Note that there is no user interface form or report associated with this data at this time.

3.2.3 STRIATION LEVEL TABLE

The only table at the striation level is FractStriation. This table contains that data collected through SEM that is applicable to a specific area on a fracture surface. Records in this table are used to capture striation counts, or to capture a crack front path across the surface. Fields within this table include:

–

3.2.4 TEMPORARY TABLES

Temporary tables are those data tables created as a results of the standard queries. These tables are temporary in the sense that the data within is erased and repopulated every time the query is accomplished.

3.2.5 OTHER TABLES

3.2.5.1 tLocations

This table is the fundamental list of all the locations within the database. This table is accessed through the fNewLocation form, includes fields necessary to add a new location and generate its ShortCode:

- *Frame* is the fuselage frame forward of the location. Because of the non- numeric plug frame names (e.g., "720D"), this frame is a text string. This is problematic for some operations. For example, the text "1178" is sorted before "360", so ascending sorts on *Frame* put the locations aft of FS 1010 in front of the forward stations. Also, though the reference frames are typically 20 inches apart, "720D" is not mathematically 20 inches different than "720C".

- *Stringer* is the nearest fuselage stringer, from S-1 to S-30.

- *Delta-FS* is the location's distance aft of the reference fuselage frame, either in inches or in hole locations (depending on the form setting), while *Delta-FS-in* is always in inches.

- *Datum-FS*, which is the number of inches aft from a reference location. This field is calculated from *Frame* and *Delta-FS*, except it is a number used for calculations and sorting, addressing all of the issues discussed above at *Frame*.

- *Delta-S* is the location's distance circumferentially from the reference stringer, either in inches or in hole locations, depending on the form setting. *Stringer-in-in* is always in inches.

- The Pitch and Offset fields (*LFastPitch, LFastOffset, CFastPitch, CFastOffsetfields*) are fastener spacing values used to compute location inches from hole number.

- *Structure* and *Detail* fields define the nature of the damage or location, as shown in Figure 1-1.

Visual Basic code within the **fNewLocation** form calculates the ShortCode from these values, and populates the *ShortCode* field. Note that unlike the location level tables discussed in section 3.2.1, this table does not use the *ShortCode* as a no-duplicates key.

3.2.5.2 BayPhotographs

This table contains information on graphic images which are associated with a complete frame bay, rather than with a specific ShortCode as in the Photographs table (see section 3.2.1.1). The

location for these images is identified by frame and stringer only, such as "540~4R" for the frame bay aft of FS 540 along stringer S-4R. The four fields within this table are:

- *Frame* and *stringer*, to designate the image's location
- *Photo Link*, which is the file name of the graphic image
- *Caption*, which is the caption to be attached to the image.

3.2.5.3 tKeywords

This table contains the list of keywords contained in the photograph captions, such as "NDI", "Macro", and "Striation". This table has two fields: the keyword, and the associated sequence number. The photograph query tool uses the sequence number to order the returned photographs in the resulting form or report. In general, photographs are returned in the following order:

- Frame bay photograph for a specific frame bay, then locations within that bay
- NDI screens, from standard methods to the emerging methods
- Stereo fractographs, from low magnification to high magnification
- SEM fractographs, from origin to crack tip, and from low magnification to high magnification

3.2.5.4 Other reference tables

These tables contain reference information, and are used in drop-down menus to minimize data entry errors:

- **Frames** is a list of all of the fuselage frames in the constant section of the B727
- **Stringers** is a list of all the stringers within the fuselage constant section
- **Panels** is a list of the fuselage panel sections removed from the project aircraft, as designated in the Target Structure Report.

3.2.6 QUERIES

Queries are used to extract data from the tables using questions presented in a predefined format. The query result typically contains the data from each record that satisfies the given criteria. For example, to determine which locations in the Field Inspection Table had rejectable LFEC indications, a query would be applied to the table to filter all records where the LFEC field contained "rejectable". The result of the query is a table containing only those records.

Currently there are five queries within the database, with more to be developed. Detailed specifications for each Query are contained in Appendix A. There are several queries which are described in this report but are hidden in the database. These queries should not be modified by the user since they are integrated into a form operation.

3.2.6.1 qLocations

This query orders the entries in the **tLocations** table into an intuitive order. The locations in **tLocations** are in no particular order. **qLocations** is the same data, but order by

1. Reference Frame (using *Datum-FS*)
2. Reference Stringer, S-1 to S-30, left then right
3. Inches Up/Down from Stringer
4. Inches Aft of Frame

This sequence means that data is generally reported from airplane nose to tail. But at a lap joint, all the upper row fasteners within a frame bay reported together fore-to-aft, followed by the stringer locations fore-to-aft, followed by the lower row fasteners.

3.2.6.2 qInspection

This query combines data from the two tables of inspection results, **tFieldInspection** and **tInspectionResults** (see sections 3.2.1.2 and 3.2.1.3), into a single table, order as in section 3.2.6.1.

3.2.6.3 qTEMPPhotoUnion and qTEMPPhotoResultCombined

qTEMPPhotoUnion combines the bay level photographs of **tTEMPPhotoResultBaySorted** with the location level photographs of **tTEMPPhotoResultSorted**. qTEMPPhotoResultCombined orders qTEMPPhotoUnion by the sequence field, to order the photographs by keywords in the forms and reports.

3.3 OTHER DATABASE ELEMENTS

In addition to the tables, there are several other elements that make up the database:

Forms provide a graphical user interface for working with the database. Tables and queries can be edited directly, but this editing requires user expertise in MS Access. A form provides a method to perform the same tasks in a user-friendly way. Forms can be written to populate tables, build queries, write reports, and many other database tasks. Some of the most critical forms are:

- **Start_Screen** is the main menu form, with links to forms to accomplish specific tasks.

- **fNewLocation** is used to add a new location to the database, populating **tLocations** table (see 3.2.5.1)

- **fStandardQueries** is the link to the three query functions below. In each case, Visual Basic code within each form is used to build a custom SQL query.

  Inspection Query Form is used to generate a report of inspection and characterization results, as in section 2.1 of the tutorial.

  fPODParametric is used to perform a parametric study of inspection and characterization tabular results, as in sections 2.2 and 2.3 of the tutorial.

  fFindPhoto is used to find photographs meeting certain conditions, as in section 2.4 of the tutorial.

- **Preferences** sets the user preferences, limited at this version to the location of the image files (path to CD or hard drive).

Reports are a pre-formatted output, typically based on a query result. Just as a form is a user-friendly way to input data or commands, a report is a user-friendly way to output data.

rTEMPInspectionResults is the inspection/characterization report shown in Figure 2-1.

rTEMPPhotoResult is the Large Format report shown in Figure 2-6.

rTEMPPhotoResultColumn is the two column report shown in Figure 2-7.

Modules are Visual Basic codes typically included in the design of a Form. Often this code executes based on an event within the form, such as when the user presses a particular button. VB codes also calculate quantities within the form. For example, the user of the SEM form inputs striation counted over what distance, and at what location; VB code within the form calculates the associated crack growth rate and the distance from the origin.

4 PLANNED ENHANCEMENTS

The database at its current revision satisfies the requirements of the Initial Database in that it provides a rigorous structure to capture the data collected during Phase 1 of the project. However, it is expected that the database will undergo significant revisions as the project proceeds and the nature of the data collected evolves. Some additions and changes currently planned to the MS Access database include:

- Improved keyword capability to sort the returned photographs. The database currently includes the sort feature, but the keywords used in the captions and the specifics for an intuitive sequence are still being improved.

- Tables to contain results from the FASTER testing. Graphical results can be incorporated into the existing table, but additional tables are required to capture strain gauge and crack length measurements as a function of cycles.

- Forms and reports to output the striation level data. The tables have already been incorporated, but standard methods of data output have not been accomplished.